Environmental design and educational performance

with particular reference to ‘green’ schools in Hampshire and Essex

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The aim of this article is to investigate the argument that attention to environmental conditions in the classroom helps support the delivery of the curriculum. There are two interconnected themes: first, that energy efficiency leads to quasi-natural environments in schools which are valued by teachers and pupils and, second, that sustainable architectural design can be an important aspect in raising educational standards or altering the perception of a school. These themes are explored within the context of the much earlier approaches to design such as the open-air school (1907) movement and also from more recent initiatives such as the Academies programme (1998), Classrooms of the Future (2000) and Schools for the Future (2004). The object is to speculate on the relationship between sustainable design and learning in general and to explore in greater detail the particular lessons to be drawn from two clusters of green schools in Hampshire and Essex.

The open-air school movement

Natural conditions in the classroom have long been regarded as beneficial to student learning. Early in the twentieth century the UK built a number of open-air schools which it was believed benefited the health, well-being and learning of children, especially those from disadvantaged backgrounds. The first such was established in 1907 by the LCC at Bostall Wood near Woolwich and it was followed by similar schools mainly for 9–13 year olds in Bradford, Halifax, Sheffield and Norwich (Turner, 1972, p. 58). The open-air school movement had originated in Germany and was thought to enhance the educational, health and welfare role of schools by the provision of high levels of sunlight and natural ventilation and through a regime of physical exercise. Typical was Whitby Road Infants’ School in Sheffield, built in 1914, which on the suggestion of the City Medical Officer incorporated a plan to maximise access to sunshine and cross-ventilation (Turner, 1972, p. 59).

Although initially a concept aimed at alleviating conditions for children in deprived urban areas, the ethos of the open-air school had begun by the 1920s to influence school design more widely. Pressure from Medical Officers of Health for more sunshine in the classroom and higher levels of ventilation (to reduce the spread of disease) led to schools which local education authorities believed also benefited children's general educational attainment. These early quasi-natural schools were not generally fully open-air but contained classrooms with verandas and outdoor terraces reached by french windows. By 1934 the Hadow Report on the Primary School was able to state that the more 'closely the primary school approaches that of the open-air school the better' (p. 117). The report confidently highlighted the beneficial affects of sunshine and ventilation to both the general health and the educational attainment of pupils.

A few years later, however, the focus shifted to the primary importance of daylighting, since it was believed that poorly lit classrooms were damaging the eyesight, concentration levels and hence learning of children. Research conducted in 1938 jointly by the Building Research Station (BRS) and Medical Research Council (MRC) established that classroom lighting was more important than ventilation in terms of the concentration level of children (RIBAJ, 1947, pp. 1–7). Daylight was seen as crucial to the development of skills such as reading. As a result classrooms in pre-war schools were often highly glazed and not infrequently poorly heated (Saint, 1987, p. 37). The impetus to maximise daylighting in the classroom gained further momentum in the post-war building programme. Of the four environmental sciences impacting upon the school (lighting, heating, ventilation and acoustics) it was lighting which most interested architects and educators alike. The Ministry of Education school building regulations of 1945 established a daylight factor in the classroom of 2 per cent (subsequently increased to 5 per cent in technical memoranda), with the result that by the 1950s schools were very highly glazed.

It is clear, therefore, that for much of the first half of the twentieth century importance had been attached to daylighting as the most important of the environmental conditions influencing learning in the classroom. However, the pre-war priority afforded to sunlight gave way to mechanical measures of daylight levels after the war, with the 'daylight factor' becoming by the 1950s the principal tool of classroom design guidance. The effect was to move the focus of attention from the relation between lighting levels and learning to one where the classroom environment as a whole was to be designed and monitored against light levels, both natural and artificial. The early belief nurtured by Hadow that the sunlit open-air school helped with physical and mental development was overtaken after the war by the adoption of broader measures aimed at achieving optimum lighting and comfort levels for teacher and pupil alike. The problem with the notion of *comfort* was the assumption that artificial conditions led to better heating and more uniform lighting and hence educational efficiency.

More recently the government has sought to look again at the classroom environment, particularly in the context of comfort and architectural design. The 'Classrooms of the Future' initiative announced in 2000 by the schools Minister, David Milliband, aimed to explore the relationship between a 'pleasant and comfortable environment for learning' and whether 'architectural and design features' can 'stimulate children's imaginations' (DfES, 2000). Similarly the initiative known as Schools for the Future (2004) has addressed *design* as an important factor in the development of exemplar projects. Milliband has called for these to be 'imaginative and sustainable' as well as flexible and adaptable (DfES, 2004). Similarly the earlier Academies Programme (1998) has highlighted the role played by architectural design in bringing about educational improvement, particularly in the cities. The Chief Inspector of Schools, David Bell, has, however, admitted that 'inappropriate buildings' remain a limiting factor in addressing underachievement in the country's most deprived communities (*Guardian*, 4 August 2005). What is back on the political agenda is not only the design of school buildings but broader questions such as sustainability and educational achievement.

This is the background to the examination of a number of 'green' schools built in the period immediately before the initiatives listed above. In the 1970s and 1980s the need to address energy conservation as a result of political instability in the Middle East led to the construction of a number of schools, mainly in Hampshire and Essex, built to sustainable design principles. They were based upon the need to maximise daylight levels and exploit passive solar heating and natural cross-ventilation in an attempt to reduce dependence upon fossil fuels. Their design mirrored in many ways the principles of the open-air school movement and anticipated the new directions initiated by the DfES under Milliband. Although some fifty green schools were built in the period 1980–95, they have not hitherto been the subject of systematic examination. The key question is whether such schools have led to improvement in educational standards as well as saving energy in the running of the school.

Measuring the performance of green schools

The research described in this article builds upon work undertaken at the Martin Centre at Cambridge University, particular Diana Haigh's investigation into the reaction of users to different environmental conditions in five passive solar schools in Essex (Haigh, 1982). Hitherto the emphasis in 'building use studies' had been upon the performance of the building, not upon the users of that building. Haigh highlighted the importance to the teacher (and hence learning) of the quality and naturalness of the classroom environment. This led to a fresh approach to the environmental design of school buildings which was tested at Netley Abbey Infants' School in Hampshire, designed in 1982 under the direction of chief architect of Hampshire County Council, Colin Stansfield Smith. This school was itself monitored, with the feedback leading to design guidance which was adopted in the construction of several further 'green' primary schools in Hampshire. Some of them are the subject of this study.

The Cambridge research was the result of collaboration between users (teachers and education authorities), academics and architects. The innovations which followed led to design solutions which were novel and at times at variance with Department for Education (DfE) guidelines, where the emphasis was on comfort rather than naturalness. However, many of the Hampshire and Essex schools attracted attention by winning a variety of environmental design or education awards (Weston, 1989). Typical was Queen's Inclosure School at Cowplain, Hampshire, which won both the BBC and the RIBA national design awards in 1990, and Notley Green School in Essex, which won both RIBA and Royal Fine Art awards . What these schools had in common was the incorporation of a number of low-energy, environmental or ecological design principles.

The research method employed in the research uses both empirical and observational techniques and is based upon comparing qualitative and quantitative data from a number of paired 'green' and 'ungreen' primary schools. A triangulation of statistical data (mainly OfStEd) covering educational attainment, exclusions and teacher turnover is employed to evaluate school performance against LEA and national averages. The evidence employed is a mixture of measures aimed at testing the effect of design in its broadest sense upon teaching and learning and evaluating them against plan variables. School league tables, examination performance indicators at Key stages 1 and 2, levels of absenteeism and exclusions, teacher turnover and OfStEd reports are used in preference to the more mechanical building performance measures adopted by earlier researchers (Hawkes, 1996, pp. 135–6). In examining a mixture of published and unpublished data on the performance of the paired green and orthodox (ungreen) schools it avoids the subjective nature of relying upon user reaction alone. In this study broad statistical comparisons are set against detailed observations, interviews and comments on school design and classroom environments. The latter are particularly relevant, for since 1999 OfStEd inspectors have been required to report on the suitability of the school for delivering the national curriculum, particularly the classroom environment.

Against the definition employed for a green school, fifty-four were identified (mostly primary schools) in the UK as having been built between 1980 and 1995, and this necessarily limits the statistical modelling which underpins the subsequent analysis of individual buildings. The primary schools monitored employ a variety of green design approaches, from natural ventilation in the classroom, made possible by elaborate roof sections and skylights, to those with atria or glazed malls, and those with classrooms incorporating large south-facing windows linked to conservatories or external verandas. What the green schools had in common was a tendency to run counter to DfE (now DfES) practice, which favoured compact, open-plan, flat-roofed schools. The adoption of passive solar principles by architects necessitated south-facing classrooms, often linked to central glazed atria which sometimes contained auxiliary teaching pods. As a result the schools investigated gave greater prominence to sunshine, nature and the external school landscape than normal schools built at the time. So a further question raised was whether the green buildings with their climate-responsive and often organic characteristics better suited the psychological needs of children and possibly teachers. Put simply, do green schools create teaching environments which better support concentration levels and learning, as was claimed earlier by advocates of the open-air schools movement? In conclusion three related questions were addressed:

1 Do green schools provide teaching and learning benefits beyond those of their more orthodox counterparts?
2 What is the perception of green schools by the major stakeholders (teachers, OfStEd inspectors)?
3 What aspects of classroom design appear most critical in enhanced educational performance?

It is necessary briefly to outline the methodology employed for identifying green schools and in selecting control group schools for the pairings. As mentioned, green and control schools are paired, providing a picture of comparative performance which, as far as possible, allows 'design type' to be the factor which distinguishes the two groups. However, it is acknowledged that other 'cultural' variables exist which are difficult to eliminate. For the sake of the analysis, the categorisation of a green school draws upon three widely adopted definitions: 'sustainable development' (Brundtland), 'sustainable design' (Foster & Partners) and 'sustainable construction' (BSRIA). The three scales – development, design and construction – employed in these definitions allow the 'green' school to address issues at the community, building and interior design levels. Out of these definitions come four key characteristics used here to identify a green school:

1 Resource-efficient, particularly in the terms of energy use.
2 Healthy, both physically and psychologically.
3 Comfortable, responsive and flexible.
4 Based upon ecological principles.

Each characteristic is itself subject to subdivision, creating twenty critical factors:

Resource-efficient
1 Low-energy design (in construction and occupation).
2 Exploits renewable energy.
3 Puts energy controls in the hand of the occupants (with appropriate education).
4 Conserves water.
5 Local sourcing of construction materials.
Healthy
6 Minimum internal pollution.
7 Uses natural materials.
8 Exploits natural light and ventilation.
9 Addresses psychological welfare.
10 Accessible to all.

Comfortable

11 Attractive and responsive internal environment.
12 Sheltered, sunny external environment.
13 Noise-free.
14 Controllable environment.
15 Glare-free.

Ecological

16 Exploits recycling.
17 Life-cycle impact.
18 Makes nature visible.
19 Designed upon ecological principles.
20 Uses ecological accounting (eco-footprint).

Not all the 'green schools' monitored employ all twenty factors: there is necessarily selection to meet circumstance. For the sake of this research, however, a green school is one which takes account of at least 75 per cent of the key factors, i.e. fifteen of the twenty listed. As a consequence the list is a useful guide in:

1 Selecting characteristic green schools for evaluation.
2 Discussing key design criteria with teachers, pupils, administrators, etc.
3 Identifying likely design factors which may influence productivity, performance or behaviour.

The research identified fifty-four green schools constructed between 1975 and 1995. The list includes schools of various types (infant, junior, secondary and city technology college) and those which incorporate a range of sustainable design features. Some exploit passive solar design, others maximise natural light and ventilation by adopting shallow floor depths and stepped sections, others use thermal flywheel technology, whilst others maximise the use of locally sourced building materials (to reduce embodied energy), others still seek to make nature visible inside and outside the classroom inspired by Building Bulletin 71 (*The Outdoor Classroom*, 1991). Others achieve energy efficiency by using mechanical as against natural ventilation, by exploiting, for example, heat-pump technology to conserve resources, whilst a further few exploit renewable energy. All were built before more recent government initiatives, such as the Academies programme and the Classrooms of the Future, although interestingly they adopt many of the proposed measures.

Geographically there are two clusters of green schools which meet the criteria: in Essex and in Hampshire (Table 1). In both counties the local education authority (LEA) had sought to build schools which bring to the fore the design challenge of sustainability. However, in both LEAs schools have been built which do not meet the green criteria listed earlier. These have become the control group schools which allow a comparison of performance with the green schools. Elsewhere in the UK less concentration of green schools exists but there remain useful examples to test the hypothesis from across the country.

Table 1 Green schools in Essex and Hampshire

Name of school	*LEA*
Notley Green Primary	Essex
Tendring Secondary	Essex
Cherry Tree Primary	Essex
St Peter's Primary	Essex
Great Leighs Primary	Essex
Nabbots Junior	Essex
Ravenscroft Primary	Essex
Thorpe Bay Secondary	Essex
Roach Vale Primary	Essex
Barnes Farm Primary	Essex
Mistley Norman Primary	Essex
Newlands Primary	Hampshire
Stoke Park Infants'	Hampshire
Velmead Infants'	Hampshire
Queen's Inclosure Primary	Hampshire
Whiteley Primary	Hampshire
Elson Infants'	Hampshire
Burnham Copse Infants'	Hampshire
Hook with Warsash Primary	Hampshire
Woodlea Primary	Hampshire
Bosmere Middle	Hampshire
Frogmore Secondary	Hampshire
Hulbert Middle	Hampshire
Farnborough Technical	Hampshire
Netley Abbey	Hampshire
Grange Junior	Hampshire

In order to select an appropriate pairing of green and ungreen schools certain similar characteristics were sought, such as geographical proximity, similarity of size, similarity of type and similarity in social/economic conditions. The latter is arrived at by using three indicators: percentage of pupils where English is not the first language; percentage of pupils with special needs; percentage of pupils with free school meals. Of the fifty-four green schools the lack of a suitable control school reduced the number of research pairings to forty-two. The concentration in this article is upon primary schools, which were found to be the most common type of green school. The pairings adopted for Essex and Hampshire are shown in Table 2.

In order to identify the broader educational benefits of the schools under investigation, five sets of performance indicators were chosen, each representing a major stakeholder interest. The first is pupil examination results, particularly at SATs Key stages 1 and 2. The second involves pupil satisfaction as measured by absenteeism rates (authorised and unauthorised) and bullying. The third set of statistics relate to teacher turnover and teaching days lost owing to illness. A further set of performance measures employed is the qualitative comments on the school environment contained in OfStEd reports and a number of interviews conducted with teachers or subject heads. From these different perspectives it is possible to gain insight into the school building as an element in the delivery of teaching and learning. As mentioned earlier, initial data gathering led the researchers to focus on primary schools, where attention to sustainable design was most prevalent. Information was available for the clusters of similar school types, allowing the author to speculate upon those green design characteristics which appeared to have most impact on learning.

Table 2 Example of pairing of green and control (ungreen) primary schools in Essex and Hampshire based on similar social, geographical and size characteristics

County	*Pair No.*	*Green school*	*Control school*
Essex	1	Cherry Tree	Lexden
Essex	2	St Peter's	Heathlands
Essex	3	Great Leighs	Latchingdon
Essex	4	Nabbots	Perryfields
Essex	5	Ravenscroft	Frobisher
Essex	6	Roach Vale	Parson's Heath
Hampshire	1	Newlands	Potley Hill
Hampshire	2	Queen's Inclosure	Morelands
Hampshire	3	Whiteley	Park Gate
Hampshire	4	Hook with Warsash	Hamble
Hampshire	5	Woodlea	Holme
Hampshire	6	Bosmere	Barncroft
Hampshire	7	Hulbert	Purbrook
Hampshire	8	Grange	Mayfield

The findings: benefits and problems

Putting aside reservations regarding the size of the sample and the difficulty of arriving at sound control pairs, the findings suggest that at SATS Key stages 1 and 2 the green primary schools in Hampshire provide an environment which leads to enhanced performance by pupils (Table 3). The figures recorded are above the LEA average and the national average for children of that age. The level of improvement of about 3–5 per cent is consistently displayed by all but one green school in Hampshire and is reflected in the LEA school rankings (Table 5). In Essex, however, there is obvious improvement at SATS 1 and 2 (Table 4), although in terms of school league tables (which employ a broader range of indicators) five out of the six green schools recorded higher positions than the control group (Table 6). Concerning 'absenteeism' the green schools show lower levels of pupil sickness among the Hampshire green schools compared with their control counterparts (Table 7) and a neutral position among the Essex schools (Table 8). However, when it comes to unauthorised absenteeism the improvement in the Hampshire schools is more marked, suggesting the pupils value being at the school, perhaps as a result of the design of the building. In Essex, on the other

Table 3 Hampshire green schools: average SATS results at Key stage 2, 1997–2000, compared with control school, LEA average and national average (rounded figures)

Name of primary school	*Green school*	*Control school*	*LEA average*	*National average*
Newlands	245	–	225	210
Potley Hill	–	235	225	210
Queen's Inclosure	230	–	225	210
Morelands	–	190	225	210
Hook with Warsash	290	–	225	210
Hamble	–	220	225	210
Woodlea	210	–	225	210
Holme	–	180		
Bosmere	260	–	225	210
Barncroft	–	170	225	210
Hulbert	195	–	225	210
Purbrook	–	235	225	210
Grange	180	–	225	210
Mayfield	–	160	225	210

Table 4 Essex green schools: average SATS results at Key stage 2, 1998–2000, compared with control school, LEA and national average

Name of primary school	*Green school*	*Control school*	*LEA average*	*National average*
Cherry Tree	130	–	215	212
Lexden	–	120	215	212
St Peter's	210	–	215	212
Heathlands	–	240	215	212
Great Leighs	235	–	215	212
Latchingdon	–	190	215	212
Nabbots	200	–	215	212
Perryfields	–	245	215	212
Ravenscroft	165	–	215	212
Frobisher	–	155	215	212
Roach Vale	205	–	215	212
Parson's Heath	–	215	215	212

hand, pupil absenteeism levels were not different between the green and control schools, although there was a marked lowering of teacher turnover rates (Table 9). So, taking SATS results, LEA school rankings, absenteeism figures and teacher turnover together, a picture emerges to suggest that productivity is higher in the green primary schools examined in Hampshire and to a lesser extent in those examined in Essex. This may be a result of design rather than green variables, since the Hampshire schools attracted more design awards and coverage in the architectural press than their counterparts in Essex. As a local education authority Hampshire believed that the messages which accompanied good design have a beneficial effect upon pupils and teachers (Weston, 1989, pp. 9–15). However, it should be noted that confidentiality of data and the small sample size limit claims that can be made of both design and sustainability.

Table 5 Hampshire green schools: LEA rankings according to school performance tables for 2000

Green school	*Control school*	*Ranking*
Newlands		102
	Potley Hill	175
Queen's Inclosure		186
	Morelands	245
Whiteley		39
	Park Gate	209
Hook with Warsash		8
	Hamble	42
Woodlea		182
	Holme	278
Bosmere		60
	Barncroft	235
Hulbert		229
	Purbrook	168
Grange		215
	Mayfield	285

Note Lower scores indicate higher-achieving school.

Table 6 Essex green schools: LEA rankings according to school performance tables for 2000

Green school	*Control school*	*Ranking*
Cherry Tree		359
	Lexden	361
St Peter’s		209
	Heathlands	234
Great Leighs		141
	Latchingdon	234
Nabbots		253
	Perryfields	170
Ravenscroft		300
	Frobisher	322
Roach Vale		178
	Parson’s Heath	252

Note Lower scores indicate higher-achieving schools.

Table 7 Hampshire green schools: authorised absence in 2001

Green school	*Control school*	*% of pupils absent*
Newlands		3.6
	Potley Hill	3.9
Queen’s Inclosure		n.a.
	Morelands	4.8
Whiteley		4.6
	Park Gate	5.5
Hook with Warsash		4.4
	Hamble	5.0
Woodlea		5.0
	Holme	4.9
Bosmere		4.8
	Barncroft	5.1
Hulbert		4.9
	Purbrook	5.4
Grange		3.7
	Mayfield	n.a.

Note *n.a.* Not available.

Table 8 Essex green schools: authorised absence in 2000

Green school	*Control school*	*% of pupils absent*
Cherry Tree		4.7
	Lexden	5.8
St Peter's		4.5
	Heathlands	3.2
Great Leighs		4.8
	Latchingdon	5.0
Nabbotts		4.4
	Perryfields	4.2
Ravenscroft		7.3
	Frobisher	8.9
Roach Vale		4.3
	Parson's Heath	4.2

Table 9 Essex green schools: teacher turnover in 1998–99 (%)

Green school	*Control school*	*Turnover*
Cherry Tree		3.3
	Lexden	8.7
St Peter's		7.2
	Heathlands	10.2
Great Leighs		n.a.
	Latchingdon	0.0
Nabbotts		15.9
	Perryfields	17.3
Ravenscroft		0.0
	Frobisher	21.0
Roach Vale		11.8
	Parson's Heath	35.3

A similar picture has emerged in studies of green secondary schools, where performance indicators show improvement in examination results and lower levels of pupil absenteeism. However, the pattern is not as pronounced as in primary schools, suggesting that further work is required to establish the correlation for more senior pupils. Evidence, for example from the Probe Study of the John Cabot City Technology College in Bristol, a building noted for its attention to daylighting and other energy efficiency measures, suggests that it is teachers, not pupils, that most value the green environment. Here productivity enhancement attributed to the design of the school accounts, according to teachers interviewed, for a 4 per cent improvement in their output (Brister, 1994). The difference between teacher and pupil perception is thought to be the result of the way pupils at this level travel from classroom to classroom, thereby undermining the effect of the classroom environment on learning and behaviour (Edwards, 2003). However, as in the more recent Academies programme, 60 per cent of pupils claimed that the overall quality of design had a beneficial impact on their attitudes (Pricewaterhouse Cooper's, 2005 pp. 31–3).

A school is not only a place of learning for pupils, it is also a place of work for teachers. The research sought to establish the relation between the design of schools, subsequent comments made in OfStEd reports and the sense of well-being engendered in teachers. Do green schools with their special characteristics create a working environment which teachers value? Conversely, do poorly designed schools give a sense of under-investment in education which is not only reflected in poor pupil behaviour and test results but expressed in low teacher morale? In its report on the Elson infants' school in Gosport, Hampshire, carried out in 1999, the OfStEd inspectors reported that a 'high level of staff absences was having a negative impact upon the overall quality of teaching', and this the inspectors attributed to a number of limitations in the design of the school which they thought were adding to teacher stress.

The research highlights the importance of ensuring that the energy design strategy for the school and educational need coincide in terms of the use and management of classroom space for teaching and learning. Where a disjuncture occurs between sustainable design and curricular delivery teachers may be under additional stress, which is reflected in high levels of absenteeism or turnover. Typical problem areas identified with green schools are windows too high to open or controlled by a computerised management system (which teachers cannot override), inadequate solar shading of south-facing windows or sunlight reflecting on computer screens. In the pursuit of maximising daylight and sunlight in the classroom (for energy efficiency) temperatures are sometimes too low in the winter and too high in the summer, adding to pupil and teacher stress. When classroom ventilation systems fail to provide adequate air changes there is the temptation to employ fans, which add to noise levels and limit the audibility of the spoken word. These problems are most prevalent when schools are inadequately maintained or when the operation of environmental controls is not understood by teachers or caretakers. As a result, the research suggests, there may be pockets of teacher stress in otherwise well performing green schools. Also, the trend towards chalk-and-talk small-group teaching in the classroom results in complex control regimes for the teacher which the shape of the classroom may frustrate because of its low-energy design characteristics. Although the OfStEd comments on the school environment tend to be more favourable to the green than to the control schools examined, a number of problems were identified (Table 5). These include noise disturbance as a result of open-plan strategies, cramped space and excessive sunlight in some areas of the classroom. On the positive side there is mention of attractive teaching environments, general brightness and a stimulating ethos in the school in general.

These shed light also on the third research question addressed, which was to investigate what aspects of green design appear most influential in creating a better learning environment. The initial findings suggest that in the real world of the classroom it is difficult to be precise about design variables. However, it appears evident that those green schools which give priority to daylight and natural ventilation generally outperform other schools in the county (Table 10) and this improvement in productivity exists in both urban and rural green schools. However, not all green schools investigated perform well: there are signs that the older passive solar schools in Essex do not achieve the benefits of more recently constructed 'green' schools in Hampshire. This is attributed to the conflict between energy efficiency and ventilation: many early passive solar schools were found to suffer from lack of ventilation, leading to high CO_2 levels in the classroom. In the pursuit of energy efficiency windows were often kept closed, thereby reducing rates of ventilation, which undermined concentration and hence learning. Often, too, curtains or blinds were used to reduce sunlight penetration and this had the effect of lowering lighting levels at the back of the classroom. Moreover, since passive solar schools tended to be open in plan, noise transfer occurred between classrooms and between classrooms, corridors and other areas such as staff offices and libraries (OfStEd reports for St Peter's School and Ravenscroft School in Essex and Newlands School in Hampshire). Hence one finding is that in the pursuit of maximising daylight levels and solar heating it is important that the needs of learning and energy conservation are considered together.

The age of the school is clearly a factor in enhanced performance. The green schools examined in Essex and Hampshire are relatively young

Table 10 Comparison of selection of UK-wide green and control primary schools using OfStEd scores at 2001

Green school	*Score*	*Control school score*
Deanery	15	12
Burraton	9	11
St Cleer	12	12
Boldmere	16	14
Aspull	10	9
Christ the King	14	12
St Thomas's	14	14
New Brancepeth	14	6
Woebly	11	10
St Theresa's	15	15
Holywell	11	9
Pulham	9	15
Salehurst	12	11
Lordship Farm	13	15
Average	12.5	11.8

Note The higher the score better the performance.

buildings and the comparison was sometimes with schools built in the 1960s or early 1970s when system construction (such as CLASP) was common. The control schools were also generally built before DfEE (now DfES) published Building Bulletin 87, with its emphasis on environmental design. However, some of the control schools date from earlier in the century, when design and construction were influenced by the Hadow report and the legacy of the open-air school movement. Classrooms constructed of brick and stone with good thermal capacity, high ceilings and large windows begin to approach aspects of sustainable design found in Hampshire. Age, however, is an influence more on design philosophy, especially the use of sustainable solutions, than on construction quality.

The research has highlighted the benefits of adopting a broad strategy for achieving sustainable design. The definition of a green school cited earlier integrates resources beyond energy (such as water) and combines physical and ecological design with an interest in health and well-being. Within these parameters the Essex and Hampshire green schools achieve measurable benefits for education, although by differing percentages. The cluster of green schools in Essex mainly adopt a low-energy design approach, using mostly passive solar principles, whilst in Hampshire more varied green design strategies are employed. Whereas in Hampshire seven out of eight green schools outperform the control group, in Essex there is less obvious benefit. The answer to this anomaly (already mentioned) is the failure of passive solar schools to deal with the extremes of climate, particularly summertime overheating and wintertime under-ventilation – a problem exacerbated by global warming. A conclusion which can be drawn is that holistic green design strategies (e.g. the Hampshire model) appear to offer advantages over concentrating upon a single (i.e. low-energy) aspect of green design (e.g. the Essex model). This broader approach was supported by the introduction in 2001 of the concept of 'eco-schools' where design, construction and the curriculum are brought together (www.eco.schools.org.uk).

The qualitative research sought to establish what design factors lead to enhanced performance in the green schools. Mention was made earlier of the importance of high levels of daylight in creating a stimulating environment for pupil and teacher alike, which research in the United States has confirmed (*Washington Post*, 1996). From an environmental point of view maximising daylight reduces reliance on energy consumption for artificial lighting. Since many of the green schools examined employed passive solar principles for heating and ventilation, daylight (and sunlight) levels were higher than average. This was true not only of classrooms but also of other areas such as halls, corridors, malls and atria which are a common feature of such schools. These auxiliary spaces provided valuable supplementary spaces for group teaching or private learning. However, ventilation rates are equally important and although they can be high in schools designed to maximise solar gains for heating there can be a tendency to sacrifice ventilation levels in the pursuit of energy efficiency (*Building Services Journal*, 2001). Lack of ventilation subjects children to high levels of carbon dioxide pollution, which makes them feel drowsy, thereby affecting concentration. As a result there is a close relation between energy efficiency, ventilation and levels of learning.

Speculations and conclusions

The work undertaken suggests that school buildings designed on green principles offer benefits for the pupil and teacher alike. Although the sample size and difficulties involved in surveying, measuring and maintaining confidentiality impose methodological limitations, a number of initial conclusions can be drawn. First, evidence suggests that schools which link sustainable design with the education ethos offer potential learning advantages, and this advantage appears most marked in younger age groups of pupils. Since infants tend to stay in one classroom for long periods of time, it is there that the environmental benefits are most marked.

Second, green schools appear to provide an environment which pupils and teachers both value, and this finds expression in a number of external measures. The quality of the classroom environment resulting from green design approaches appears to reduce stress in teachers, leading to lower rates of absenteeism or staff turnover, and this in turn leads to improved productivity. The lower level of pupil absenteeism (approved and unapproved) suggests greater satisfaction with the school as a place for learning, and this is reflected in both improved SATS results and the observed reduction in the incidence of bullying. Moreover, because the green schools signal an investment in design values where health and well-being are to the fore, the buildings themselves contribute positively to the pupils' learning experience and possibly also to the wider community. In this the image of the school complements physical benefits, producing greater integration between school life and community which is reflected in improvement in educational standards. Just as the Academies programme has raised standards because of the 'messages attributed to the buildings' (Pricewaterhouse Cooper's, 2005) the same appears to be true of green schools in Hampshire and to a lesser extent in Essex.

Third, the improvement in performance of pupils appears to be related to the level of daylight in the classroom (and the presence of sunlight). However, other factors are involved such as the level of ventilation, the temperature and noise levels. These conclusions suggest that attention to daylight levels is more important than the current focus upon 'comfort'. By maximising children's exposure to daylight green schools offer investment advantages beyond that of reducing the environmental footprint of the school in terms purely of energy consumption. Although schools which consume less of their budget on utility bills have extra money available for computers or classroom assistants, the quality and type of light in the classroom appear most critical in terms of learning. In this there are similarities with green offices in the United States, where the performance of companies was directly related to the environmental standards in the workplace (Kats, 2003).

Mention was made at interviews of the enhanced image of a school designed to environmental principles which may help in the recruitment of staff, in sending the message that learning is valued and in cementing a relationship between the school and its community. A school which is cherished will be used out of hours, reducing the level of vandalism and hence money spent on repairs. In full life-cycle costing terms, green schools appear to offer a range of social, educational and community benefits. Too often with the procurement of schools under initiatives such as PFI, building costs ignore the wider implications of design, especially sustainable design.

The research described here suggests that a relationship exists between design, energy conservation and educational performance. This reinforces the National Curriculum Council's (1990) assertion that the 'spirit and ethos of the school contributes significantly towards the development of a caring attitude towards the environment'. In the Hampshire schools, in particular, the general sense of environmental harmony between school, playground and hinterland has been commented upon favourably by teachers, parent groups and OfStEd reports. What they demonstrate is that sustainability and good modern design are not inconsistent but mutually beneficial. It has to be admitted, however, that some of the green schools examined cost more to construct than the norm. In Hampshire, for example, green schools were up to 12 per cent more expensive than those constructed by other local education authorities. For example, Stoke Park School was built in 1987 at a cost of £740 million whilst the DfEE grant at the time to local education authorities was just over £700 million. However, not all Hampshire schools were more expensive: the education authority does not adopt a uniform cost for schools, believing that adjustment is needed to address local circumstances (Stansfield Smith, 2002). By way of contrast the Essex green schools, which were only marginally above government cost yardsticks, tended to achieve less tangible benefits. It has to be admitted, therefore, that cost is a factor in creating the special environments which pupils and teachers enjoy.

The positive attitudes to learning in the green schools examined generally required schools which involved additional cost to build and additional time to design. In this sense green schools are at present not a universal answer to education but they could be selectively employed to remedy particular difficulties in areas of poor educational attainment or for children with special learning needs The principles could also be applied in the retro-fit of existing school buildings, particularly those in deprived inner-city neighbourhoods. This appears to be the current government's approach in its Academies programme.

The ethos of the green school has found its way into more recent government policy such as the 'Classrooms of the Future' initiative. Here twenty-seven new primary schools are being piloted by the DfES to test whether theories of classroom design meet modern teaching practice (DfES, 2000). One theory being tested is whether architectural and design features can stimulate children's imagination (Chiles, 2003). The focus is upon healthy and responsive classroom design where there is a fluid relation between outside and inside based on the Hampshire model. Although it is too early to monitor the classrooms built under the Classrooms of the Future initiative, a survey of attitudes to classroom design suggests that greater attention to sustainable design is favoured by pupils and teachers (*Guardian*, 22 May 2001). However, those schools built under the initiative have cost £300 more per square metre to construct than orthodox schools (Chiles, 2003), confirming the importance of political priorities in realising improvement in classroom design. It remains sobering that the relatively wealthy Hampshire County Council can build schools to a green standard that few other LEAs can meet despite their arguably greater educational need.

There is a growing body of literature suggesting the learning benefits of greener classrooms. The work in the UK is confirmed by that elsewhere relating not only to schools but to a wider range of working environments (Edwards, 2003; Kats, 2004). However, the limited number of green schools available for modelling makes it imperative that as the 'Classrooms of the Future' and 'Schools for the Future' initiatives get under way further studies are conducted. It is vital that the anticipated £7 billion investment in schools over the next decade learns from a proper analysis of these pioneers. The French philosopher Roland Barthes has described the classroom as 'four walls around a future'. Lord Foster has tested this with his Bexley Academy in south London with its sustainable credentials and classrooms with one side without walls. The future will inevitably need to address the environmental challenge, and there is no better place to introduce green ideas than the primary-school classroom.

Green schools: design and management strategies

- Maximise classroom daylight levels to enhance concentration.
- Ensure solar strategy is matched by adequate levels of ventilation.
- Maintain acoustic protection in open-plan areas.
- Use secondary solar or buffer spaces (conservatories, atria) for casual teaching and learning.
- Justify additional cost by benefits to learning and teacher retention rates.
- Place environmental controls in the classroom under teachers, not the caretaker.
- Keep green design strategies simple and understandable.

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